The influence of the built environment on real world car efficiency

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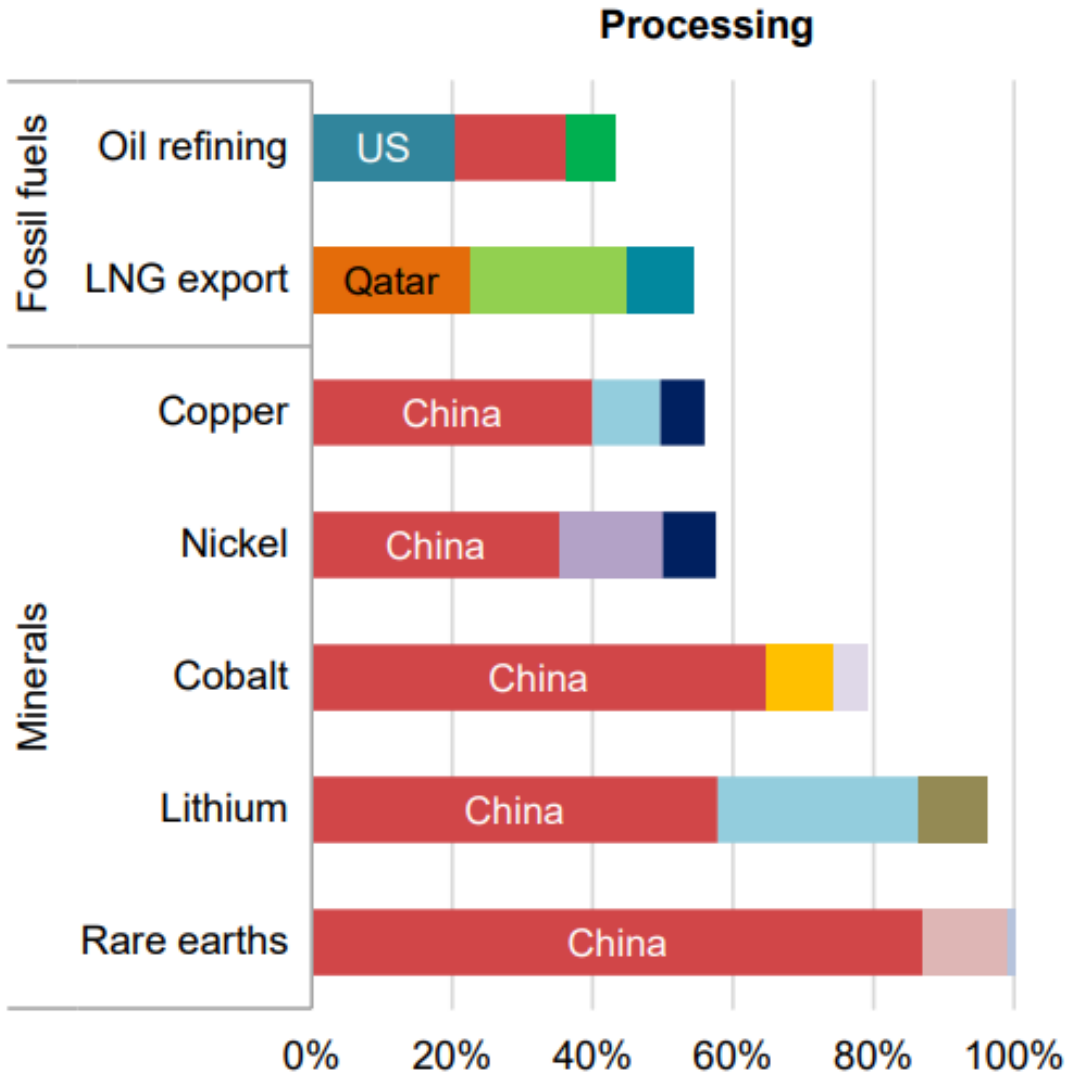
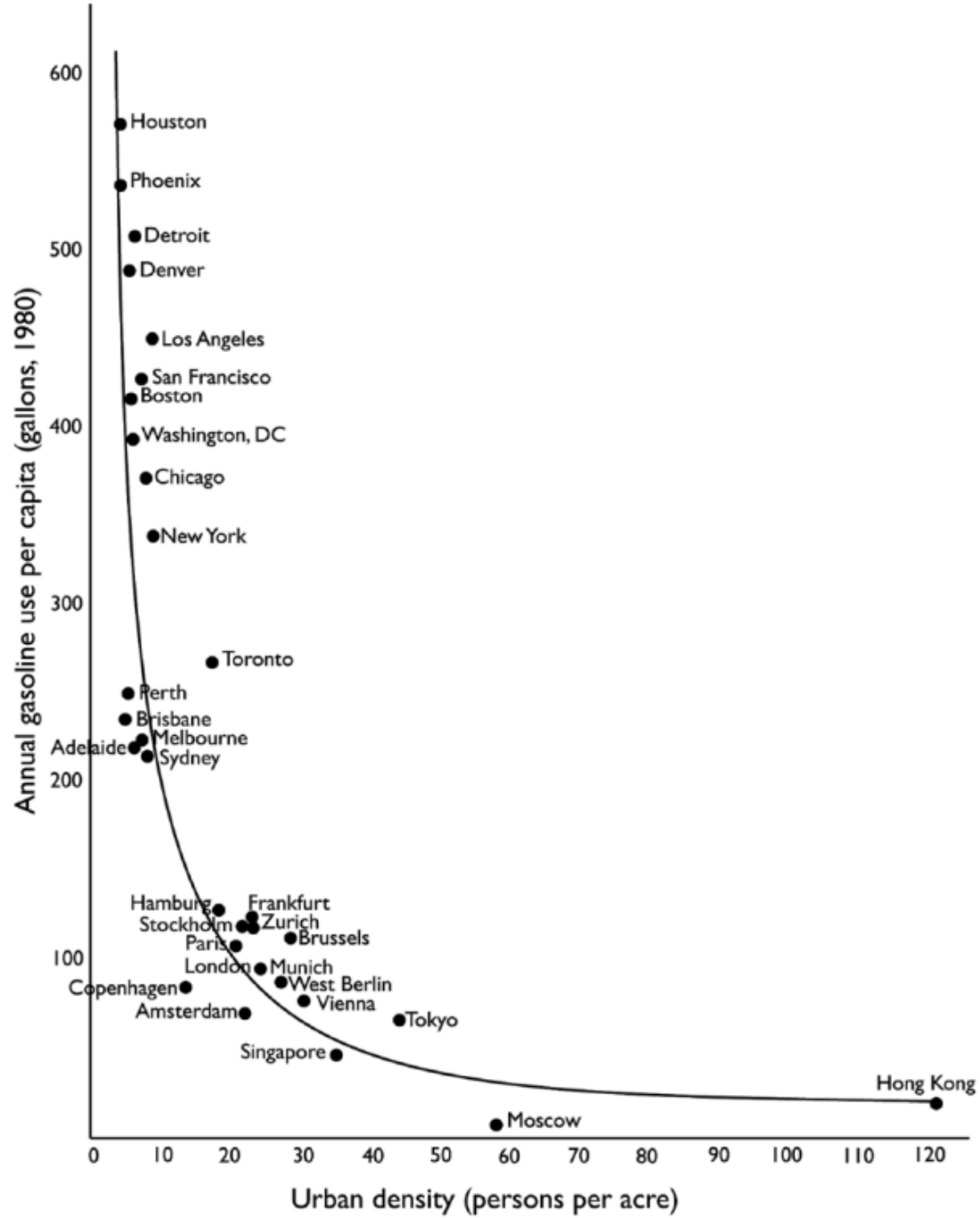
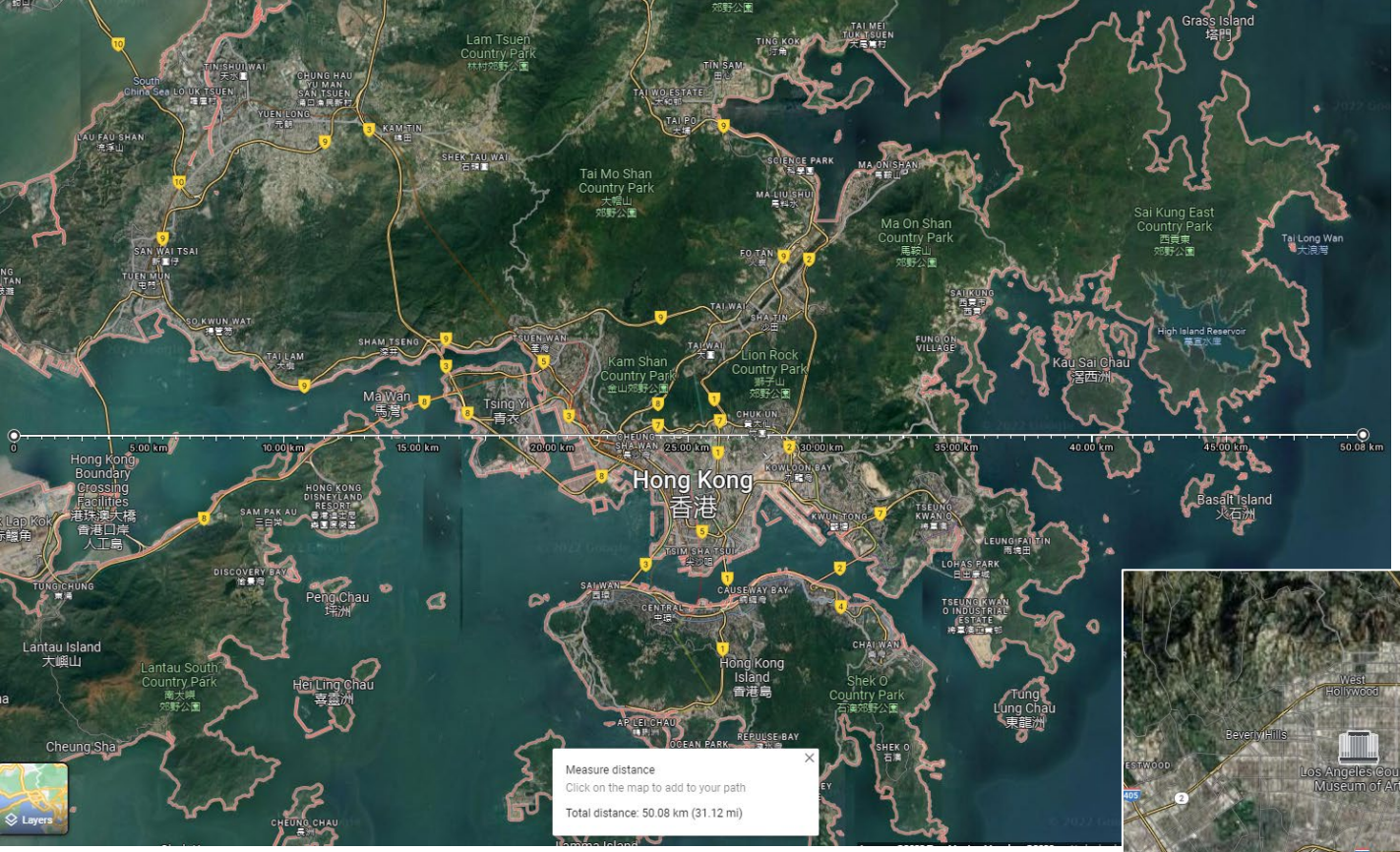
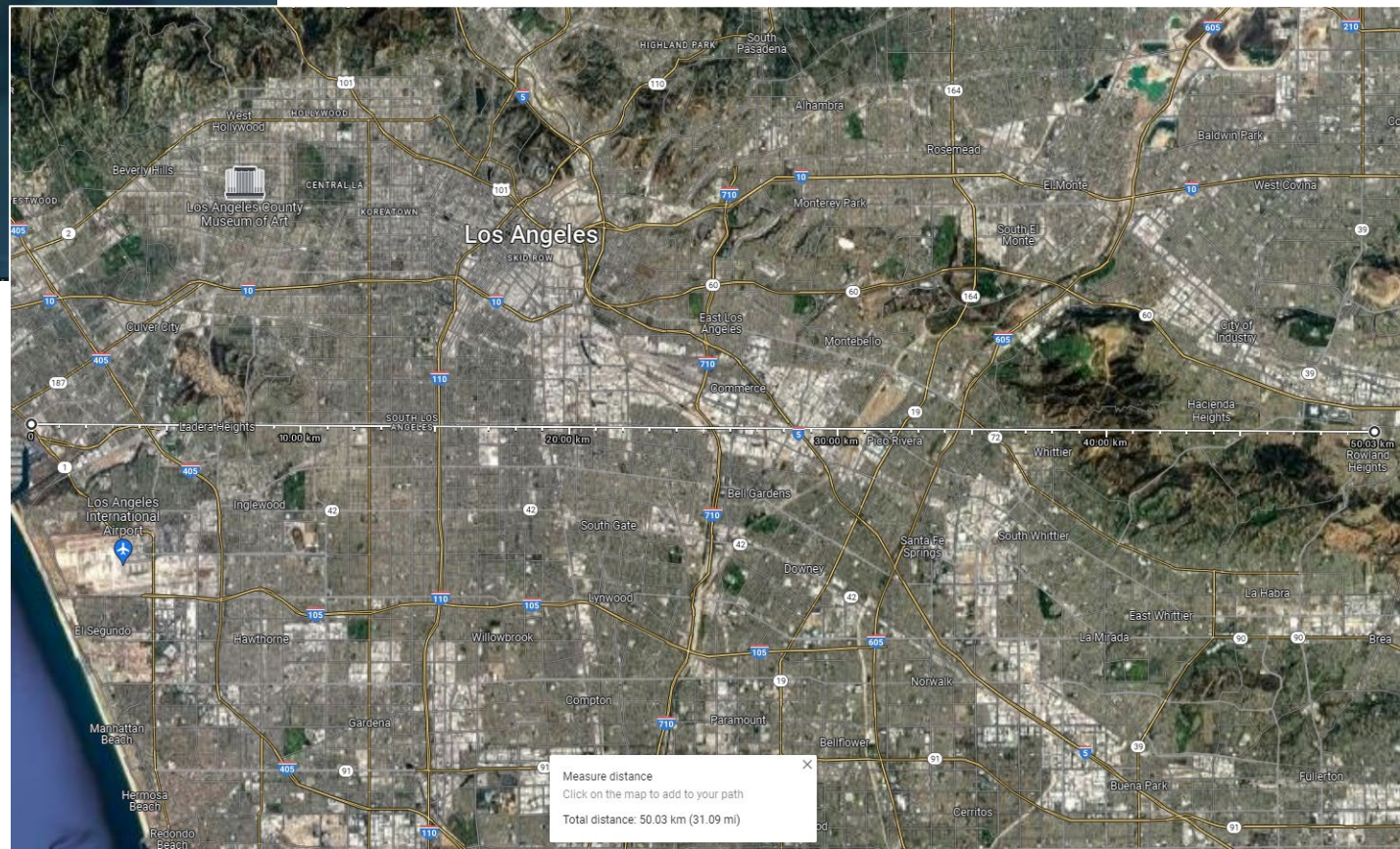
Why this topic?

- **We need to reduce gasoline consumption**
  - Climate change
  - Energy security
- **EVs also threaten energy security**
- **Heavy EVs consume a lot of electricity**
  - At the wrong time
- **Important to also reduce car dependence and minimize car weights and associated energy consumption**




Annual gasoline use per capita (gallons, 1980)
600
500
400
300
200
100
Houston
Phoenix
Detroit
Denver
Los Angeles
San Francisco
Boston
Washington, DC
Chicago
New York
Toronto
Perth
Brisbane
Melbourne
Adelaide
Sydney
Hamburg
Frankfurt
Stockholm
Zurich
Brussels
Paris
London
Munich
West Berlin
Copenhagen
Vienna
Amsterdam
Tokyo
Singapore
Hong Kong
Moscow
0
10
20
30
40
50
60
70
80
90
100
110
120
Urban density (persons per acre)


Hong Kong
香港
Measure distance
Click on the map to add to your path
Total distance: 50.08 km (31.12 mi)
Layers

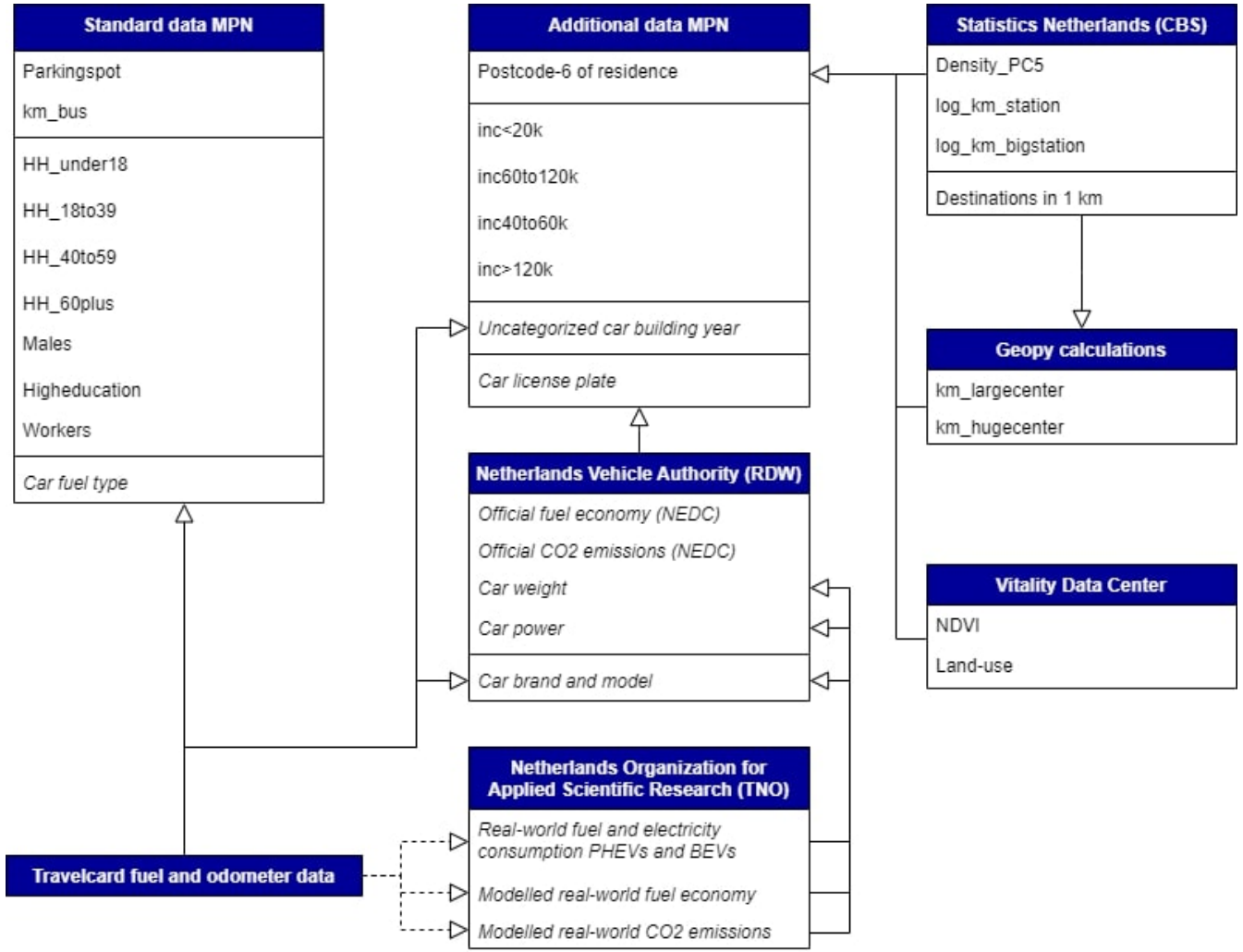

Los Angeles
Measure distance
Click on the map to add to your path
Total distance: 50.03 km (31.09 mi)

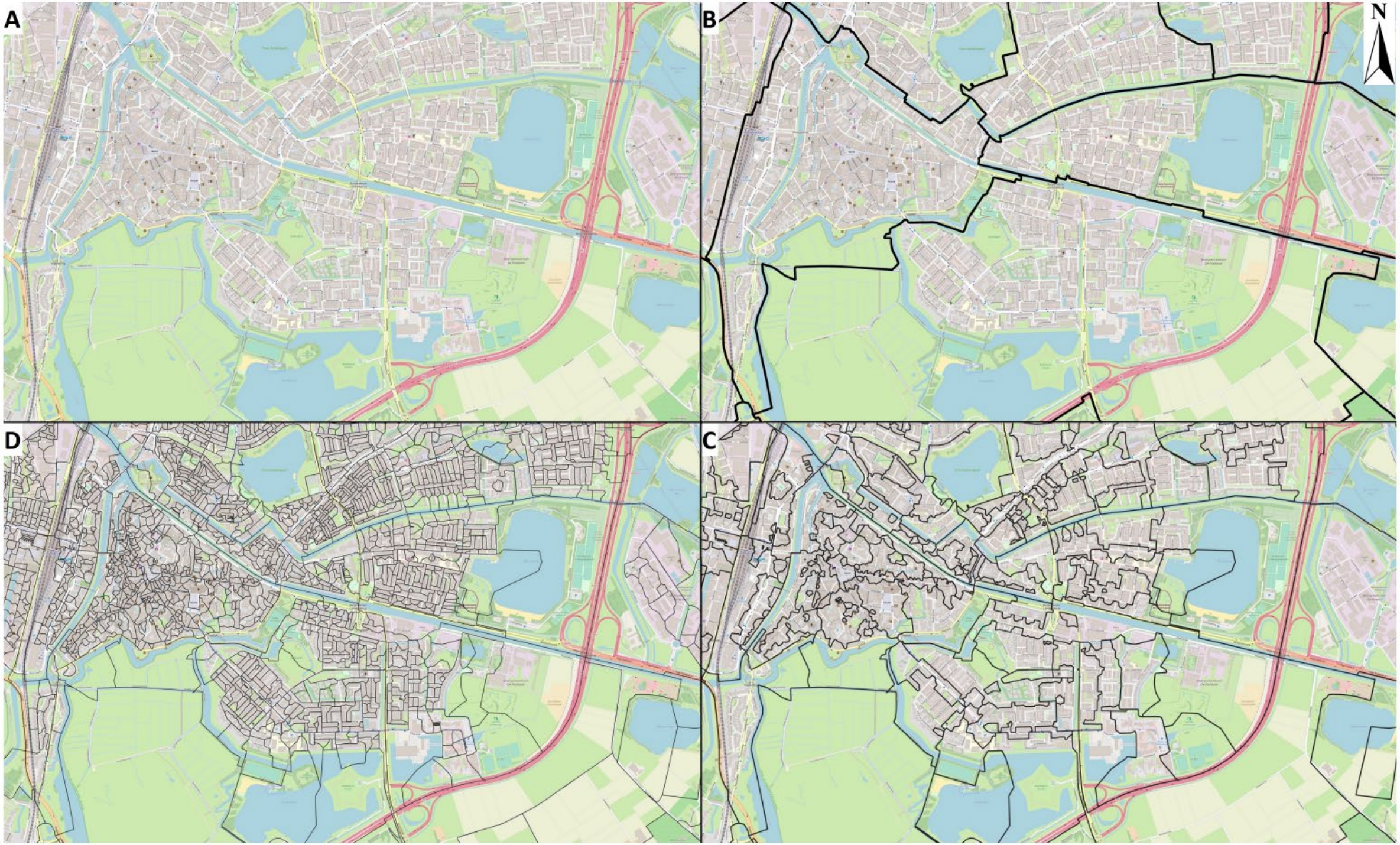
The research gap

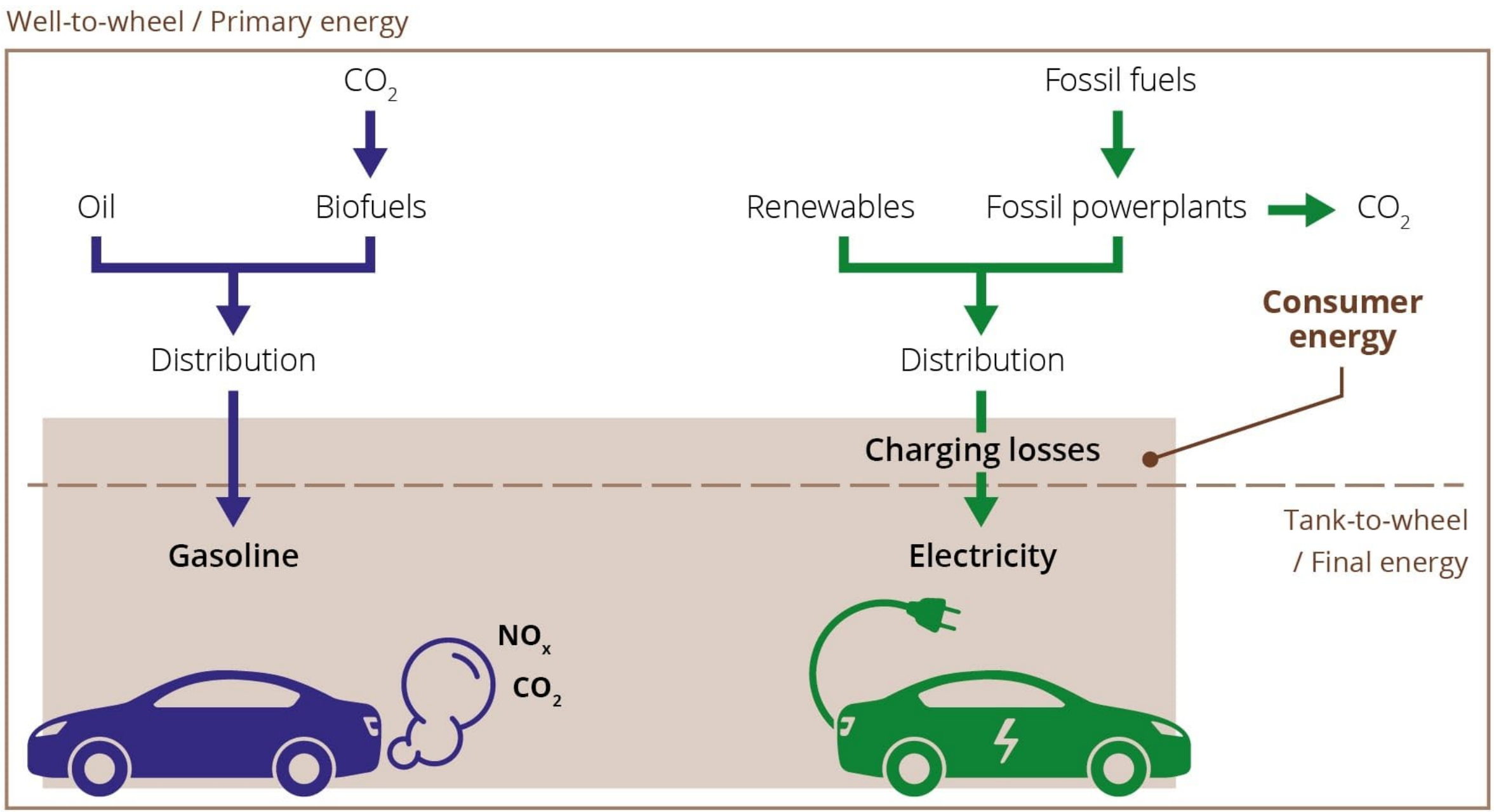
- **Most studies analyze vehicle kilometers traveled**
- **Other studies analyze ownership cars vs SUVs, vans, and trucks**
  - Most omit compact (efficient) vehicles
  - They do not actually compute energy use
- **Studies that did analyze vehicle energy:**
  - Often have limited representation built environment
  - Often use biased official data
  - Do not classify vehicles by weight

The data

- **MPN travel and sociodemographic data**
- **MPN, CBS, and VDC built environment data**
  - In 1km buffer around Postcode-6 (1234AB)
- **Travelcard and TNO energy data**
  - Official NEDC-data



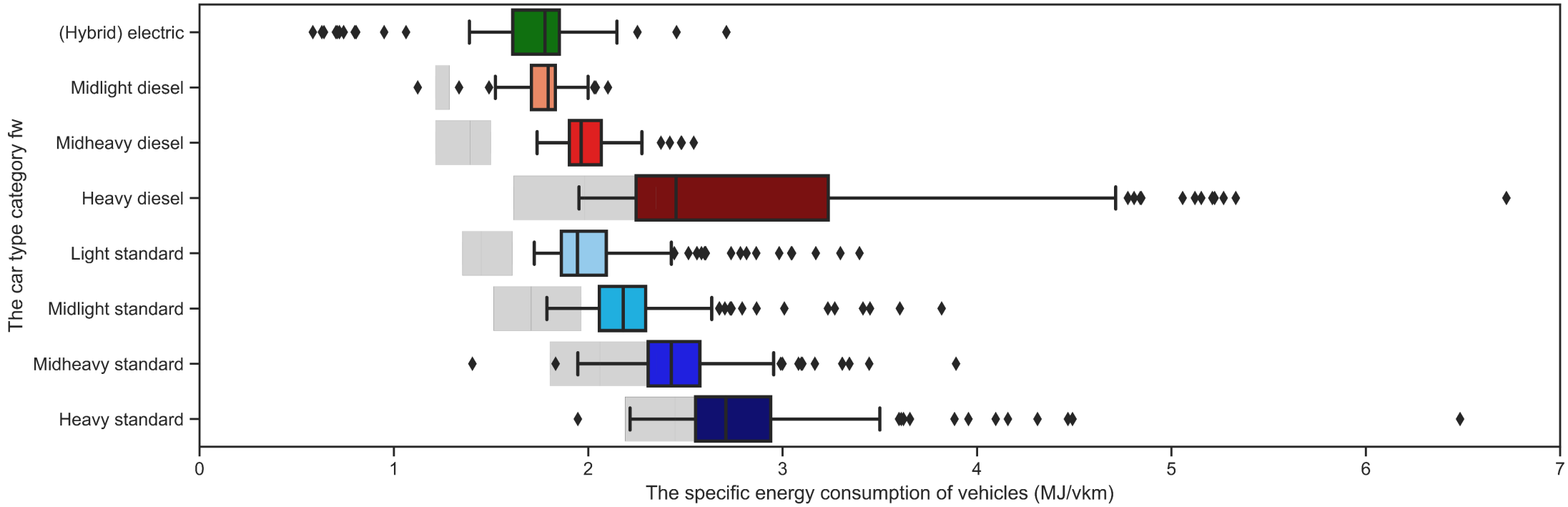

A
B
N
D
C


Well-to-wheel / Primary energy
CO_2
Fossil fuels
Oil
Biofuels
Renewables
Fossil powerplants
CO_2
Distribution
Distribution
Consumer energy
Charging losses
Gasoline
Electricity
Tank-to-wheel / Final energy
NO_x
CO_2

Car energy use

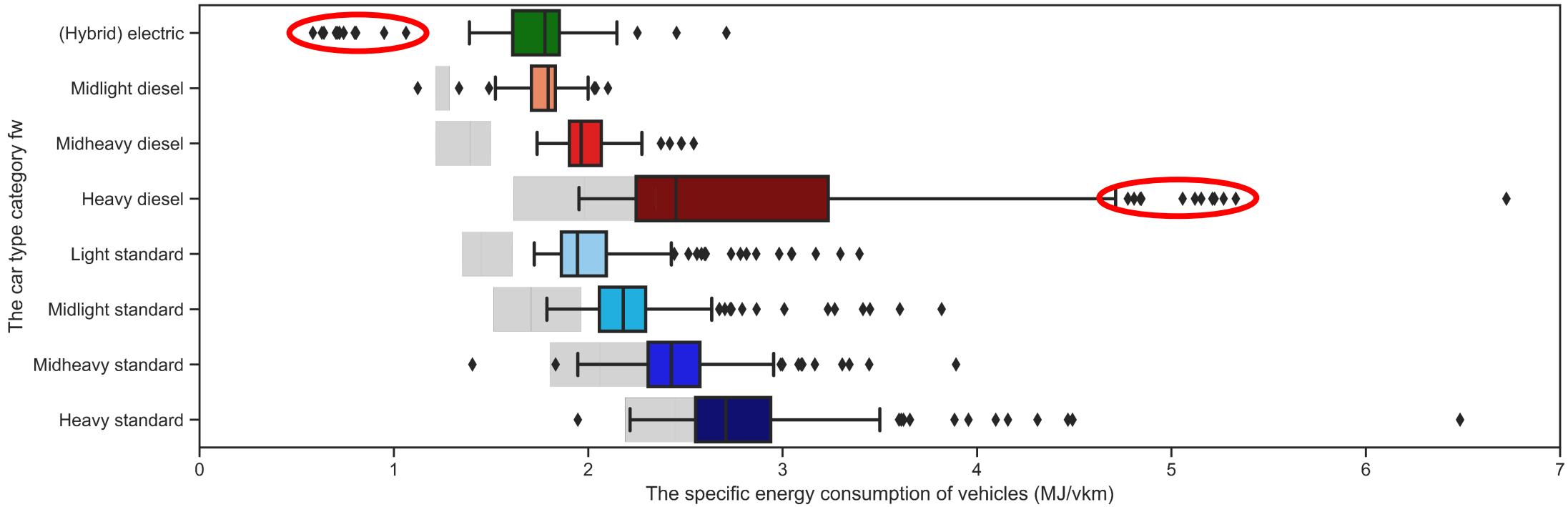
- ❖ Boxplots show specific energy use per fuel and weight based car type category fw
- ❖ Box shows three quantiles (middle line median) and whiskers/diamonds show outliers
- ❖ Three quantiles according to official data in Grey

- ❖ Multilinear model of real-world vehicle energy (MJ/vkm) depending on variables



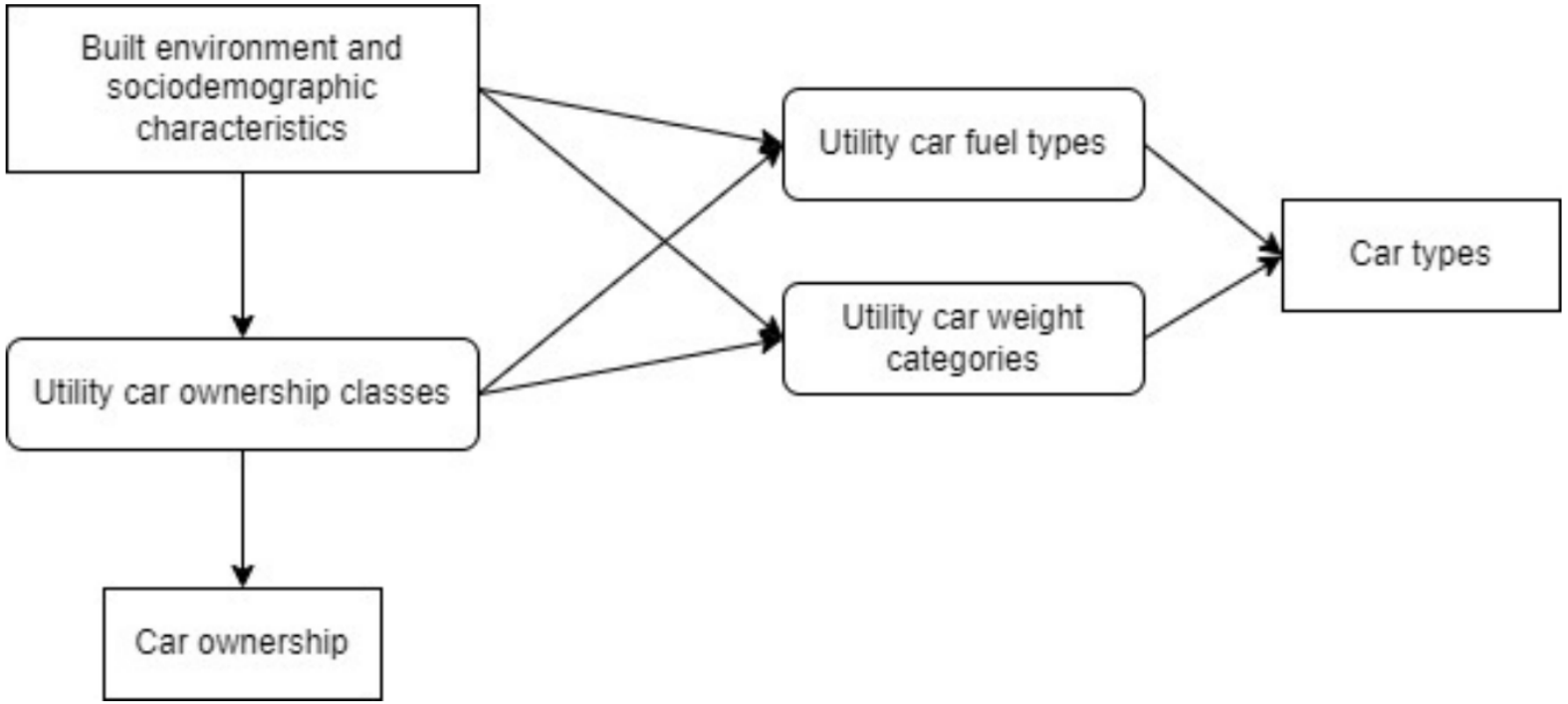
Multilinear model?

- **Outliers**
  - Half of the vehicles use 2-2.4 MJ/vkm
  - Model cannot predict which households much more or less efficient vehicles
- **Differing dependence fuel type, weight, and building year on variables**
  - Rich people buying both efficient Teslas and gas-guzzling SUVs



A different approach

Multilevel discrete choice model with explicit consideration of fuel- and weight-based preferences



Results

❖ **Let me break it down for you**

Latent class model of car ownership

Onecar class utility	**Coef β_c**	**Std err**	**t-score**	**P-value**	**Multicar class utility**	**Coef β_c**	**Std err**	**t-score**	**P-value**
Aspecific Constant	2.004	0.060	33.2	0.000	**Aspecific Constant**	0.763	0.076	10.1	0.000
HH_under18	0.435	0.066	6.6	0.000	**HH_under18**	0.533	0.071	7.5	0.000
HH_18to39	0.571	0.072	8.0	0.000	**HH_18to39**	1.571	0.084	18.8	0.000
HH_40to59	0.598	0.072	8.3	0.000	**HH_40to59**	1.579	0.084	18.8	0.000
HH_60plus	1.160	0.078	15.0	0.000	**HH_60plus**	2.032	0.107	19.1	0.000
inc<20k	-0.292	0.036	-8.2	0.000	**inc<20k**	-0.384	0.082	-4.7	0.000
inc40to60k	0.196	0.045	4.3	0.000	**inc40to60k**	0.304	0.061	5.0	0.000
inc60to120k	0.313	0.062	5.0	0.000	**inc60to120k**	0.613	0.070	8.7	0.000
inc≥120k	0.155	0.078	2.0	0.047	**inc≥120k**	0.252	0.080	3.1	0.002
					Males	0.164	0.057	2.9	0.004
Workers	0.375	0.050	7.5	0.000	**Workers**	1.052	0.076	13.8	0.000
Density_PC5	-0.307	0.041	-7.4	0.000	**Density_PC5**	-0.705	0.075	-9.4	0.000
log_km_station	0.165	0.049	3.4	0.001	**log_km_station**	0.272	0.063	4.3	0.000
log_km_bigstation	0.125	0.050	2.5	0.012	**log_km_bigstation**	0.177	0.069	2.6	0.010
km_hugecenter	0.162	0.043	3.8	0.000	**km_hugecenter**	0.142	0.058	2.4	0.015
km_bus	0.246	0.085	2.9	0.004	**km_bus**	0.350	0.090	3.9	0.000
Parkingspot	0.252	0.046	5.5	0.000	**Parkingspot**	0.398	0.059	6.8	0.000

Multinomial model of fuel- and weight-based car types

Aspecific Constants	**ASC_t**	**Std err**	**t-score**	**P-value**	**Standard fuel type utility**	**Coef β_f**	**Std err**	**t-score**	**P-value**
Standard_light	0.344	0.166	2.1	0.039	2car Constant (β_{2car})	-0.174	0.267	-0.7	0.514
Standard_midlight	1.116	0.135	8.3	0.000	**HH_18to39**	0.108	0.067	1.6	0.105
Standard_heavy	-1.961	0.302	-6.5	0.000	**inc<20k**	0.221	0.077	2.9	0.004
Diesel_midlight	-1.230	0.168	-7.3	0.000	FracAdultHighedu	-0.071	0.049	-1.5	0.147
Diesel_midheavy	-0.951	0.170	-5.6	0.000	**FracAdultMales**	-0.166	0.057	-2.9	0.004
Diesel_heavy	-1.428	0.227	-6.3	0.000	**km_largecenter**	0.149	0.053	2.8	0.005
HEV	-1.390	0.227	-6.1	0.000	**km_hugecenter**	-0.228	0.073	-3.1	0.002

Diesel fuel type utility	**Coef β_f**	**Std err**	**t-score**	**P-value**	**HEV fuel type utility**	**Coef β_f**	**Std err**	**t-score**	**P-value**
2car Constant (β_{2car})	-2.656	0.444	-6.0	0.000	2car Constant (β_{2car})	-0.328	0.383	-0.9	0.391
HH_18to39	0.699	0.111	6.3	0.000	HH_60plus	-0.216	0.116	-1.9	0.064
HH_40to59	0.463	0.097	4.8	0.000	inc≥120k	0.067	0.046	1.5	0.146
Workers	0.396	0.099	4.0	0.000	**Higheducated**	0.229	0.097	2.4	0.018
km_largecenter	0.224	0.074	3.0	0.003	**Parkingspot**	0.234	0.096	2.4	0.015
Landuse	-0.121	0.068	-1.8	0.076					
Parkingspot	0.155	0.081	1.9	0.055					

Light weight utility	**Coef β_w**	**Std err**	**t-score**	**P-value**	**Midlight weight utility**	**Coef β_w**	**Std err**	**t-score**	**P-value**
2car Constant (β_{2car})	-0.609	0.324	-1.9	0.060	**2car Constant (β_{2car})**	-1.552	0.258	-6.0	0.000
HH_under18	-0.372	0.064	-5.8	0.000	**HH_under18**	-0.220	0.052	-4.3	0.000
HH_40to59	-0.169	0.066	-2.5	0.011	**HH_60plus**	-0.249	0.073	-3.4	0.001
HH_60plus	-0.661	0.085	-7.8	0.000	**inc≥120k**	-0.092	0.045	-2.1	0.040
inc40to60k	-0.116	0.058	-2.0	0.044	**Workers**	0.236	0.068	3.5	0.001
inc60to120k	-0.149	0.064	-2.3	0.020	km_hugecenter	0.123	0.076	1.6	0.109
inc≥120k	-0.198	0.078	-2.5	0.011					
Males	-0.355	0.065	-5.5	0.000					
km_hugecenter	0.201	0.088	2.3	0.022					
NDVI	-0.125	0.061	-2.1	0.039					
Parkingspot	-0.096	0.058	-1.7	0.097					

Midheavy weight utility	**Coef β_w**	**Std err**	**t-score**	**P-value**	**Heavy weight utility**	**Coef β_w**	**Std err**	**t-score**	**P-value**
2car Constant (β_{2car})	-1.864	0.567	-3.3	0.001	**2car Constant (β_{2car})**	1.194	0.280	4.3	0.000
HH_40to59	0.185	0.112	1.7	0.098	**HH_under18**	0.141	0.057	2.5	0.014
inc60to120k	0.356	0.083	4.3	0.000	**HH_18to39**	-0.309	0.085	-3.6	0.000
Workers	0.267	0.146	1.8	0.067	**HH_60plus**	0.190	0.090	2.1	0.035
NDVI	0.297	0.110	2.7	0.007	Higheducated	0.113	0.070	1.6	0.103
					Males	0.331	0.098	3.4	0.001
					Parkingspot	0.212	0.075	2.8	0.005

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inc<20k	-0.292	0.036	-8.2	0.000	**inc<20k**	-0.384	0.082	-4.7	0.000
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HH_40to59	0.463	0.097	4.8	0.000	inc≥120k	0.067	0.046	1.5	0.146
Workers	0.396	0.099	4.0	0.000	**Higheducated**	0.229	0.097	2.4	0.018
km_largecenter	0.224	0.074	3.0	0.003	**Parkingspot**	0.234	0.096	2.4	0.015
Landuse	-0.121	0.068	-1.8	0.076					
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HH_under18	-0.220	0.052	-4.3	0.000
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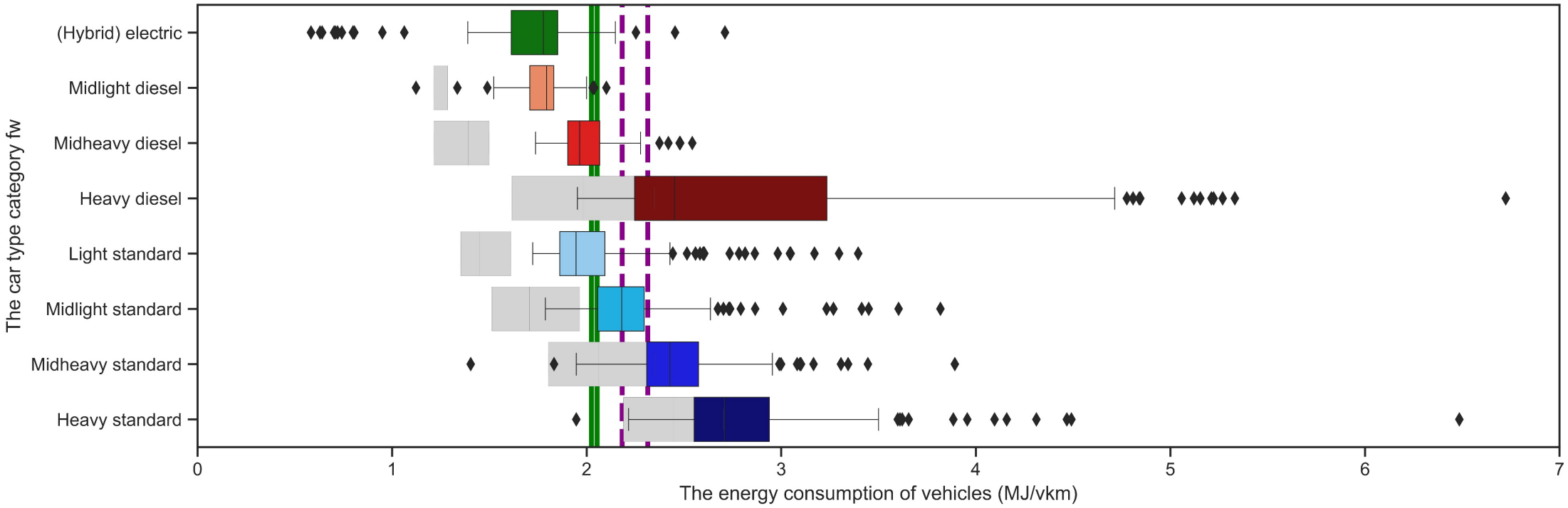
HH_40to59	0.185	0.112	1.7	0.098
inc60to120k	0.356	0.083	4.3	0.000
Workers	0.267	0.146	1.8	0.067
NDVI	0.297	0.110	2.7	0.007

Heavy weight utility	Coef β_w	Std err	t-score	P-value
2car Constant (β_{2car})	1.194	0.280	4.3	0.000
HH_under18	0.141	0.057	2.5	0.014
HH_18to39	-0.309	0.085	-3.6	0.000
HH_60plus	0.190	0.090	2.1	0.035
Higheducated	0.113	0.070	1.6	0.103
Males	0.331	0.098	3.4	0.001
Parkingspot	0.212	0.075	2.8	0.005

Predictions

- **Simple predictions to help understand results:**
  - Vehicle energy use of student and high-income family
  - In Amsterdam city center and representative village of Heesch
- **The student (green lines) owns an efficient car in both Amsterdam and Heesch**
- **A high-income family (purple lines) owns a less efficient car, especially when living in Heesch**



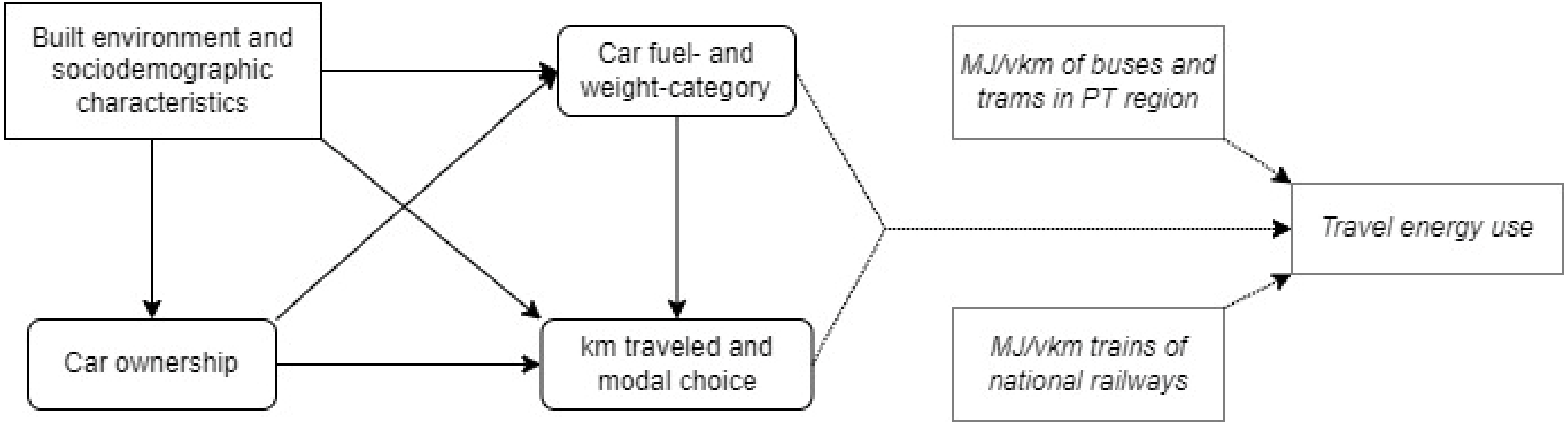
Conclusions

- Multicar households live in non-urban environments and prefer inefficient heavy vehicles
- Small, lower-income households with few male or older members own light vehicles
- Urban households own light vehicles
- Households with private parking own both heavy and electric vehicles

- Studies that omit vehicle efficiency therefore somewhat underestimate influence urban planning interventions on future energy/emissions
- But most effective energy-saving strategy seems to keep improving testing procedures

What now?

- **Adding kilometers traveled and modal preferences**
  - **Km/mode = fraction(mode)*km_total**
- **Modeled vehicle kilometers by car can be combined with MJ/vkm of fuel- and weight-based car type to predict energy use**
- **However, the model is highly sensitive to starting values because of latent class structure and non-normal distribution of kilometers traveled**



Research questions

1. **How do the residential environment and sociodemographic characteristics influence the number of cars owned by households?**
2. **How do the residential environment, sociodemographic characteristics, and number of cars owned influence the fuel- and weight-based types (and thus energy efficiency) of the cars owned?**
3. **How do the residential environment, sociodemographic characteristics, number of cars owned, and types of cars owned influence distances traveled and modal choice?**
4. **What is the combined effect of the residential (built) environment on travel energy as determined by the types of cars owned, distances traveled, and modal choice?**

Want to talk further?

Feel free to send a mail
or connect on LinkedIN!

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